# Measurement of noise from sound sources placed close to the ears

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# MEASUREMENT OF NOISE FROM SOUND SOURCES PLACED CLOSE TO THE EARS

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## Abstract

The paper describes and compares two methods for noise assessment from sound sources placed close to the ears, in which the ear exposure is either measured with a head and torso simulator or in real ears. The results are consequently converted into the corresponding free-field related levels. Both methods are being standardized by ISO TC 43/SC 1/WG 6. The investigation is presented in more detail in Hammershøi and Møller [1].

## 1 Introduction

Human noise exposure is normally evaluated using sound pressure at the position of an exposed person, measured without the person, although the exposures of the person's ears differ from this exposure. However, the method is easy to handle in real life, and the frequency weighting curves and the procedure in general (including our knowledge about effects of noise) have been established with a reference to the sound pressure measured this way.

One might say that the procedures have been adapted so as to counteract the difference between the sound pressure at the ears and the sound pressure without the person. This works well when the sound field of the exposure situation is comparable to the sound field for which the procedures have been developed, but problems occur when the exposure field differs from these, for instance when the sound source is close to the ears.

### 1.1 Standardization

The working group 6 under Technical Committee 43 ("Acoustics") was formed with the purpose of developing a standard, which can be used for situations, where the sound pressure level measured at the position of the

exposed person but with the person absent does not adequately represent the sound exposure.

In order to make it possible to assess the exposure by means of well established criteria, the exposure of the ear is measured and subsequently converted into a corresponding free-field or diffuse-field level. The result is given as free-field related or diffuse-field related equivalent continuous A-weighted sound pressure level, $L_{Aeq,FF}$ or $L_{Aeq,DF}$.

The method will be described in ISO 11904, which is a series of standards. In part 1 of ISO 11904 the measurements are carried out with miniature or probe microphones inserted in the ears of humans (MIRE-technique). In part 2 the measurements are carried out with a manikin, equipped with ear simulators including microphones (manikin-technique).

Both methods strive for the same results. However, usually they yield different uncertainty which may influence the choice of method, and guidance is therefore given in an annex of the standards.

## 1.2 Measurement principle

If the MIRE-technique is applied, then miniature microphones or probe microphones are placed to measure the sound pressure at a position in the ear canal. The subject is exposed to the sound source(s) in question, and for each of the ears the ear canal sound pressure level is measured in one-third-octave frequency bands.

Each of the one-third-octave levels is adjusted with the *free-field* or *diffuse-field frequency response*[1] to obtain corresponding free-field related or diffuse-field related one-third-octave sound pressure levels. These one-third-octave levels are adjusted using A-weighting factors, and subsequently combined to obtain the free-field related or diffuse-field related equivalent continuous A-weighted sound pressure level $L_{Aeg,FF}$ or $L_{Aeq,DF}$.

The measurements are carried out for both ears of human subjects and the mean of these measurements is determined. The free-field or diffuse-field frequency response shall be taken either from the appropriate listing in the standard, or determined for each individual subject and ear as described in the standard.

If the manikin-technique is used, the measurement of sound exposure is performed by exposing the manikin to the sound source(s) in question and

[1] The free-field frequency response is the same as the Head-related Transfer Function (HRTF) with sound coming from the front. The diffuse-field frequency response can be determined as an average of HRTFs for many angles, where a weigthing of the HRTFs (corresponding to the space angle that each HRTF represents) is used.

using the permanent microphones mounted in the manikin for the measurement of ear canal sound pressure level.

### 1.3 Purpose of present investigation

It is the purpose of the present investigation to disclose and compare the primary uncertainties of the two methods. The results of the investigation will be presented in more detail in [1]. In the following sections of this paper only examples of the considerations made in the working group are described. In the oral presentation of this paper data examples will be presented, but these were not available at the time of submission.

## 2 MIRE-TECHNIQUE

The method with real-ear measurements requires that measurements are made for a number of subjects, so that the final average of the results will adequately represent the population. It is the author's experience from previous investigations of the sound transmission to and within the human ear canal with free-field and headphone exposure that the variation subjects in between vary with the choice of ear canal measurement point (Hammershøi and Møller [2], and Møller et al. [3], [4], [5]).

In the analysis of the sound transmissions in the two exposure situations an analogue model has been used to split up the transmissions into elements, which turns out not to vary equally subjects in between. Since the transmission elements do not vary independently (because of a strong correlation some of the elements in between), it is not trivial to determine the optimal ear canal measurement point for all situations. The factors that affect the uncertainty of the final result are - among others - physical position of measurement point, number of subjects, and the method of determining the free-field or diffuse-field frequency response.

As suggested in the Introduction of this paper, the free-field frequency response may be taken from listings of the standard, and the working group is presently collecting data for that worldwide.

## 3 MANIKIN-TECHNIQUE

With the manikin-technique the human subject is replaced by a dummy (also denoted Head and Torso Simulator, abbreviated HATS, or artificial head), which has microphones placed in the ear canals. This should simplify the measurement of the noise exposure, but it only represents the noise exposure of humans, if the manikin has the same acoustical properties as the average or typical human.

In a parallel investigation [6] it was found that existing artificial heads only poorly represent the average or typical human, when the heads are compared to humans in a listening test, and measurements of the Head-Related Transfer Functions of humans and artificial heads support this

conclusion (data yet unpublished in written form). Standards for such manikins do exist, however, also the data for the standards seem to deviate from data from humans.

Another practical problem with the artificial heads is the softness of the pinna simulators. Many artificial heads have rather stiff ears, which do not yield for the pressure of the headphone capsules in the same way as a human ear. Therefore, it is sometimes difficult to place headphones properly on the artificial heads.

## 4 CONCLUSION

In order to investigate the uncertainties of the methods described, a comparison including measurements at various points in the ear canal of humans and measurements using the manikin-technique with different sound exposures will be made. The measurements will be processed to give the final free-field related or diffuse-field related equivalent continuous A-weighted sound pressure level.

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